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THE NORTH SASKATCHEWAN RIVER

MERCURY PROJECT

1972 - 1973

- by -

B. A. MUNSON and E. E. DANIEL

University of Alberta

Edmonton, Alberta

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FOREWORD

The preparation of this research paper on mercury pollution was made possible through the co-operative efforts of many individuals and organizations, as acknowledged by the authors at the end of the report.

The success of this project gives support to the Alberta Environment policy of involving individuals, environment organizations, corporations or any others having an interest in pollution control or environmental management and research.

The project was initiated largely through the leadership of Staff Sgt. A. W. Toeppner, of the City of Edmonton Police Fish and Game Association. The Interdisciplinary Committee for Environmental Quality at the University of Alberta provided the scientific direction. Twenty-seven companies, individuals and organizations provided money, equipment, and other help. Such widespread public involvement speaks well for citizen involvement in environmental management and pollution control.

The Alberta Department of the Environment was able to offer financial support in 1972 and 1973 which aided in bringing the research to a successful conclusion. The association of the Research Secretariat with the project and the people who carried it out has been most profitable.

S. B. SMITH
Chairman
Research Secretariat.

ABSTRACT

Several species of fish sampled from the North Saskatchewan River near Edmonton, Alberta exhibited varying concentrations of mercury in muscle tissue. Three species of sucker (*Catostomus catostomus, C. commersoni, Moxostoma macrolepidotum*) and pike (*Esox lucious*) contained concentrations below the currently accepted Canadian standard of 0.5 ppm set by Federal regulations on consumable poultry, fish and meat. One species (*Hiodon alosoides*), the most abundant in the North Saskatchewan River contained mercury levels in excess of 0.5 ppm.

Checks of a number of effluent sources entering the North Saskatchewan River at Edmonton revealed that most of the mercury was entering the river from the outfall from the City of Edmonton sewage treatment plant. Sources from industry were consistently very low. The major contributing source was indentified as originating on the University of Alberta campus. Contributions of mercury to the river in 1972 from the University through the sewage system were high, but dropped drastically in 1973, probably as a result of expanded secondary sewage treatment and removal of sludge from the treatment plant, rather than release of sludge to the river. Levels of introduced mercury and accumulation in river sediments are very low. Effects on river biota of chronic exposure to mercury are essentially unknown.

ABSTRACT

This report summarizes two years of research on the levels of mercury pollution found in the Edmonton area and in the North Saskatchewan River system. The report is comprised of two major sections:

SECTION I - Mercury sources in the Edmonton area.

SECTION II - Mercury levels in sediments, invertebrates, and fish the North Saskatchewan River in Alberta.

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SECTION I

Mercury Sources in the Edmonton Area

Introduction

Total mercury analysis performed on the axial muscle of fish collected from the North Saskatchewan River in Alberta during the period 1969-1971 revealed mercury levels well in excess of the 0.5 ppm upper limit placed on consumable meat and fish by the Health Protection Branch. The collection of the fish was carried out by the Alberta Department of Lands & Forests, Fish and Wildlife Division, with the mercury analysis performed by the Freshwater Institute in Winnipeg (Paterson 1970). The City of Edmonton, population 400,000, is the major contributor of pollutants to the North Saskatchewan River in Alberta, both from industrial and sanitary sewage sources (Kupchanko - 1969-1972). A study was therefore initiated to determine the levels of mercury in the North Saskatchewan River in the Edmonton area and, if possible, to trace the mercury, which was being introduced, to its source.

Materials and Methods

Collection of samples of water and bottom sediments for this project commenced in May 1972 and terminated in August 1973. Sampling of river water, effluents and bottom sediments was conducted at the transects illustrated in Fig. 1.

Water and sewer samples were collected in 500 ml nalgene bottles, each containing 1 ml conc H_2SO_4. Analysis followed collection as soon as possible and the samples were stored at $4^{o}C$ until analysed.

A 500 ml nalgene bottle, containing 1 ml conc H_2SO_4, was one-half filled with the first inch of sediment from the river bottom and the bottle was then filled with river water. Sediment samples were sieved through a 100 u mesh sieve, then filtered through a #4 Whatman filter paper and frozen until analysis could begin. 0.1-0.3 grams of sediment were taken for analysis: Dry weights were determined on duplicate samples by evaporating the samples for 24 hours at $100^{o}C$. Recovery experiments on sediment samples spiked with inorganic and organic mercury yielded not less than 87 per cent recovery.

Both water and sediment samples were digested in concentrated sulfuric acid (H_2SO_4) and concentrated nitric acid (HNO_3) and then oxidized with seven per cent potassium permanganate ($KMnO_4$). Reduction of the mercury in sediment samples was accomplished with stannous chloride ($SnCI_2$) - cadmium chloride ($CdCl_2$) solution (Thorpe 1970 and Armstrong 1971).

The values expressed for each sample, both water and sediment are the mean of four (4) determinations.

National Bureau of Standards, Standard Reference Material, 1571, orchard leaves, were analysed by the above method and the total mercury content was found to be 0.147 $\pm$ 0.056 ug/g dry weight (n = 8) and sample size 0.015 ug/g dry weight on a minimum sample size of 0.25 gm; we used smaller samples because of difficulties in digesting the leaves. Recovery experiments on water samples, using Ch_3H_gCl and H_gCl_2, yielded 85-104 per cent recovery.

Results and Discussion

There were small differences in the total mercury content of river water collected upstream of all suspected mercury sources (Transect 1, Fig. 1, Table 1) when compared to samples collected immediately downstream of effluent outfalls (Transects 3 to 9).

Bottom sediment samples taken along transect 1 served as the background levels, as this location was well upstream of any suspected mercury source and levels (0.02-0.08 ug/g dry weight) obtained were indicative of non-polluted areas (Table 2) (Hartung 1972; Konrad 1971). There was no difference in samples taken from the north or south banks at this transect. Bottom sediments samples along transect (immediately downstream of effluent outfalls) had elevated mercury levels when collected from the south bank, but similar samples collected from the same transects on the north bank contained low mercury levels (Table 2). These results suggested that the effluent outfalls (industrial and sanitary sewage), which are located exclusively on the south bank, were the points of origin of mercury introduction into the river.

A sampling program of the major effluent outfalls commenced in May 1972 and was terminated in August 1973 (Table 3). The levels of mercury in these effluents was relatively low and indicated that there was no single large source of mercury but rather several small ones. Of these small sources the main sewage treatment plant was the primary source of mercury being introduced to the North Saskatchewan River in the Edmonton area on the basis of the average amount of mercury per sample combined with the outfall volume (20×10^6 gal/d - 40×10^6 gal/d).

A point of interest here is the difference in the mercury levels of the main sewage treatment plant effluent in 1972 and 1973. The City of Edmonton, commencing in the winter of 1972-73 applied secondary sewage treatment throughout the year as opposed to restricting it to the months when ice covered the river, as had been the practice in the past. Other differences in plant operations in 1972 as compared to 1973 were; increased plant capacity for secondary treatment and sludge from the sewage lagoons was not released into the river annually as was previously done, usually in late June or early July at the time of peak river flow. This sludge is presently piped approximately five miles to permanent holding lagoons. After settling, the liquid present in these new lagoons is then returned to the plant for retreatment. The precise reason for the drop in mercury levels in the main sewage treatment plant effluent during the summer of 1973, however, was never determined.

Since the effluent from the main sewage treatment plant was the major contributor of mercury to the North Saskatchewan River in the Edmonton area, it was decided to attempt to identify the source or sources of this mercury. The initial step was to examine the mercury levels present in the sanitary sewers originating from the major industrial plants (39) in Edmonton. The industrial sewer samples were 24 hour composite samples taken by means of an automatic sampler placed directly in the sewer line from each plant. The time,

duration and location of sampling (carried out by the main sewage treatment plant) was unknown to the originating plant. The results indicated (Table 4) that there was no source which was consistently high and a very low overall average prevailed throughout the plants sampled.

The next step in attempting to identify the source or sources of the mercury in the City of Edmonton sanitary sewage was to trace the mercury through the sewers. This was accomplished by commencing at the main sewage treatment plant, sampling all branches at every junction and then following the highest branch (Fig. 2). This method identified the major source of mercury but it did not identify all the sources.

Of the many sampling problems encountered, the inability to sample all the junctions on the same day proved to be the major one and accounts for the fluctuating levels in Table 5. After the major source had been identified and the appropriate manholes located, single day sampling was attempted on July 25, 1973 - Table 5 and Fig. 2 illustrate the results of this sampling run. They show very clearly that the major source of mercury is the sanitary sewers originating from the University of Alberta campus. With increasing distance from the University area along the main sewer line the higher mercury levels from the University were diluted by sewage with a lower mercury concentration entering the main line.

Since the University of Alberta campus appeared to be the major contributor of mercury to the sanitary sewer system in Edmonton, it was decided to examine the mercury levels in the sewer contents of the individual buildings on the campus. These values do not indicate total amounts of mercury being introduced to the sewer system, because the flow rates from each building varied a great deal. The North Wing of the Public Health Building contained the highest concentration of mercury in its effluent. This building housed the Pathology Department of the University of Alberta Hospital. Fig. 3 illustrates the construction of the manhole sampled which had an 18 in. reservoir or trap at the bottom and a very slow flow rate.

The sewage output from the building emptied directly into this reservoir and the input to the main sewage lines left. This reservoir acted as a settling tank for the heavy mercurial salts in the effluent. Further examination of the operations of the building revealed that the source of the mercury was in the histological stain, hematoxylin, which contained 0.5 gm of HgO (mercuric oxide) per litre of stain.

On May 1, 1973, the manhole, sewer line and reservoir were flushed, with samples being taken before and after flushing. Throughout the summer months of 1973 a rapid increase in the mercury content of the reservoir was noted (Table 6). The overall contribution of this building to the total mercury content of the sewer system was very minute because the volume of effluent was very low.

Bottom sediment analysis (Table 2) as has been stated previously, indicated that the source of the mercury which was being introduced into the river at Edmonton, was the effluent outfalls located on the south bank of the river. Each transect (3-9: Fig. 1), at which samples were taken, was located immediately downstream of an effluent outfall. It was originally thought that sediment samples taken immediately downstream of each outfall would indicate the levels of mercury being contributed to the sediment by that particular outfall. This, however, proved not to be the case, as the rate and position of sedimentation was determined by the physical state of the river, which itself was in continual fluctuation, thereby causing considerable variation in sedimentation rate and position.

Sediment analysis also indicated the effect that laminar flow has on the distribution of particulate bound mercury in the river profile, that is, restricting its distribution to an area along the originating bank. These statements were amply indicated by the results of sediment analysis for June 16, 1972, when a large increase in the mercury content of bottom sediments was ovserved (Fig. 4B). This increase occurred concurrently with the annual release of the sewage lagoons form the Main Sewage Treatment Plant into the river.

This large influx of mercury laden particulate matter also served as a valuable indicator as to the pattern of distribution of sedimentation that was occurring in this portion of the river at this time of year. The largest increase in the mercury content of the sediments occurred at transect 4 and not at transect 3, the point of release, as had been expected. The mercury content of the effluent immediately upstream of transect 4 did not increase and was therefore not the source of the increased mercury in the sediments. It was therefore determined that difficulties arise when the origin of an introduced chemical; pollutant is inferred from its sedimentation position.

In the first week of July, 1972, the North Saskatchewan River flooded its banks with a river flow rate in excess of 20,000 c.f.s. This resulted in the recently deposited mercury from the lagoon release being completely removed from our sampling area and presumably being redeposited further downstream (Fig. 4B).

Sediment analysis in 1972 illustrated the effect that laminar flow within a river profile has on the distribution of an organically bound or particulate bound pollutant, the levels and distribution of a very large input, and the natural cleansing effect of a flood. The levels of mercury found in the river environment in the Edmonton area were very low with the rate of input from several sources being correspondingly low. The major contributor was the main sewage treatment plant with the sewage lagoons contributing the largest single input. The possible effects of these levels on the river environment are unknown but would be expected to be small especially if they are removed from time to time by the flushing action of the river. The effect of these mercury levels on the biota residing in the river is unknown, however the environment which contains the mercury (south bank) also contains many other pollutants which lead to a relatively unsuitable environment which most fauna avoid (Paterson 1966). With the effect of laminar flow restricting the pollutants to the south bank there is a relatively clean, pollutant free channel on the north side of the river which affords the fauna a much more viable alternative, thereby limiting exposure to contaminants.

Conclusion

Input of mercury from the major source in Edmonton to the sanitary sewage system was high throughout the sampling period - May 1972 - August 1973, whereas the levels of mercury present in the effluent from the main sewage treatment plant dropped drastically in 1973. Probably, the expanded secondary treatment with removal of sludge from the plant, recycling of the sludge fluid and cessation of the annual sludge release from the lagoons, eliminated a sizeable portion of the mercury previously entering the river environment.

It has been shown that it is possible to trace mercury through the sanitary sewer system of a large centre like Edmonton to its major source, as well as being able to pinpoint the process and chemical compound resulting in mercury contamination of the sewage from a particular building.

Sediment samples can be utilized as indicators of mercury introduction and accumulation, with the level of and time for accumulation depending on the physical state of the river, but difficulties arise when the sedimentation position is utilized as an indicator of the input origin.

The levels of mercury being introduced into the North Saskatchewan River in the Edmonton area via sanitary sewage and industrial effluent, and its accumulation in the sediments of the river bottom are all very low. However, it should be noted that the effect of chronic exposure to such low levels of mercury on the biota of an aquatic ecosystem is essentially unknown.

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TABLES & FIGURES

FIGURE I - Map of North Saskatchewan River - Edmonton area, showing effluent outfall locations and sampling transects.

FIGURE II - Map of City of Edmonton sanitary sewers - showing sampling locations.

FIGURE III - Manhole - Public Health Building, North Wing.

TABLE I - Mercury content of the river water, North and South sides of the river, upstream and downstream of effluents.

TABLE II - Mercury levels in effluents.

TABLE III - Mercury levels in Industrial Sanitary Sewers.

TABLE IV - Mercury levels in the Edmonton Sanitary Sewer System.

TABLE V - Mercury levels in the sewers of buildings on the University of Alberta campus.

TABLE VI - Mercury levels in sediment from the N.S. River - sampled on the North and South Bank - upstream and downstream of effluent outfalls.

GRAPH I - pp6 Hg in sewers vs. distance from MSTP.

GRAPH II - Mercury content of sediments vs. transect - via month.

TABLE 1

Mercury Levels in the river water of the North Saskatchewan River in the Edmonton area.

- values in parts per billion (ppb) - µg/l

River water upstream of any suspected mercury sources - along transect 1, North & South sides of the River.		0.04 0.02 - 0.09
River water downstream of suspected mercury sources along transects 3 - 9.	Northside:	0.05 0.04 - 0.07
	Southside:	0.08 0.06 - 0.10

TABLE 2

Mercury content in bottom sediments from the North Saskatchewan River taken in the Edmonton area - May 1972 - August 1973

- values expressed in parts per million (ppm) - µg/g dryweight.

Upstream of Edmonton along Transect 1.	0.05 0.02 - 0.08
Northbank - along transects 3 - 9, immediately downstream of effluent outfalls.	0.06 0.03 - 0.09
*Southbank - along transects 3 - 9, immediately downstream of effluent outfalls .	0.21 0.12 - 0.55

*effluent outfalls originated on the South bank.

TABLE 3

Effluents contributing Mercury to the North Saskatchewan River in Edmonton.

ppb (µg/l)

	May - Dec. 1972	June - Aug. 1973
*Main Sewage Treatment Plant	0.29 0.17 - 0.38	0.08 0.05 - 0.16
Imperial Oil	0.29 0.24 - 0.37	0.17 0.02 - 0.20
Texaco Oil	0.30 0.13 - 0.37	0.35 0.27 - 0.41
Building Products	0.09 0.05 - 0.20	0.24 0.10 - 0.38
Chemcell	0.09 0.05 - 0.24	0.10 0.08 - 0.17
Uniroyal	0.11 0.05 - 0.29	0.23 0.06 - 0.41

* MSTP - major contributor due to volume of effluent - 1972 volume - 20×10^6 - 40×10^6 gals/da.

1973 - sludge no longer stored in MSTP lagoons: pumped to new permanent lagoons - fluid recycled.

TABLE 4

Mercury in Industrial Sanitary Sewage
Edmonton. Oct. - Dec. 1972

ppb (µg/l)

	No. of Plants	No. of Samples per plant	Value
	8	10	0.17 0.08 - 1.90
	2	5	0.27 0.05 - 0.54
	4	4	0.17 0.00 - 0.69
	6	3	0.17 0.04 - 0.37
	8	2	0.26 0.02 - 0.75
	11	1	0.28 0.05 - 1.19
Totals:	39 Plants	151 Samples	0.22 0.00 - 1.90

mean and range for 39 plants (151 samples) 0.22
0.00 - 1.90

TABLE 5

Mercury Trace in the City of Edmonton
Sanitary Sewers - 1972-1973
(all values in ppb-µg/l)

Map Reference			
1.	Northside Main Line	0.19 0.19 - 0.19	October 17/72
2.	Southside Main Line	0.55 0.45 - 0.67	
3.		0.86 0.85 - 0.87	October 25/72
4.		5.5 5.4 - 5.6	
5.		0.14 0.13 - 0.15	
6.		0.22 0.21 - 0.23	
7.		0.25 0.25 - 0.26	
8.		0.26 0.23 - 0.28	July 25/73
9.		0.33 0.28 - 0.38	
10.		0.45 0.45 - 0.45	
11.		0.78 0.77 - 0.79	

Mercury Content In Sanitary Sewers of Buildings on the University of Alberta Campus, August 1972 - July 1973.

(all values ppb - ug Hg/l)

Buildings	Date Sampled Aug.23/72	Sep 1/72	Nov 23/72	June 8.73	July 25/73
U of A Hospital	0.46	----	2.1	17.0	9.4
Clinical Sciences	0.54	1.16	8.0	4.2	2.7
Cancer Clinic	0.32	1.50	---	----	---
Research Council	1.00	8.3	17.0	5.0	7.8
Basic Med. Science	0.08	0.09	---	0.6	5.0
Chemistry - Med.	0.45	----	5.0	0.74	---
Agriculture	0.45	----	---	----	---
Nuclear Research	0.56	----	0.92	----	---
Biological Sciences	0.35	----	0.50	1.5	---
Physics	0.19	----	---	----	2.9
Dentistry - Pharm.	----	----	---	----	0.71
Chemistry	----	----	---	----	6.3
Public Health (South)	1.32	1.04	5.0	33.5	1.8
* Public Health (North) (Pathology Dept. U of A Hospital)	----	58.0	690.0	105.0	220.0

	Sep 7/72	Nov 13/73	Apr 22/73	May 1/73	May 1/73	May 9/75	June 8/73	July 25/73
*Public Health	58.0	690.0	900.0	1200.0 Before and after sewer flushing	0.11	75.0	105.0	220.0

*July 25th, 1973 - Complete Sewer run - City and University - Samples taken during 2 hour period.

FIGURE 1

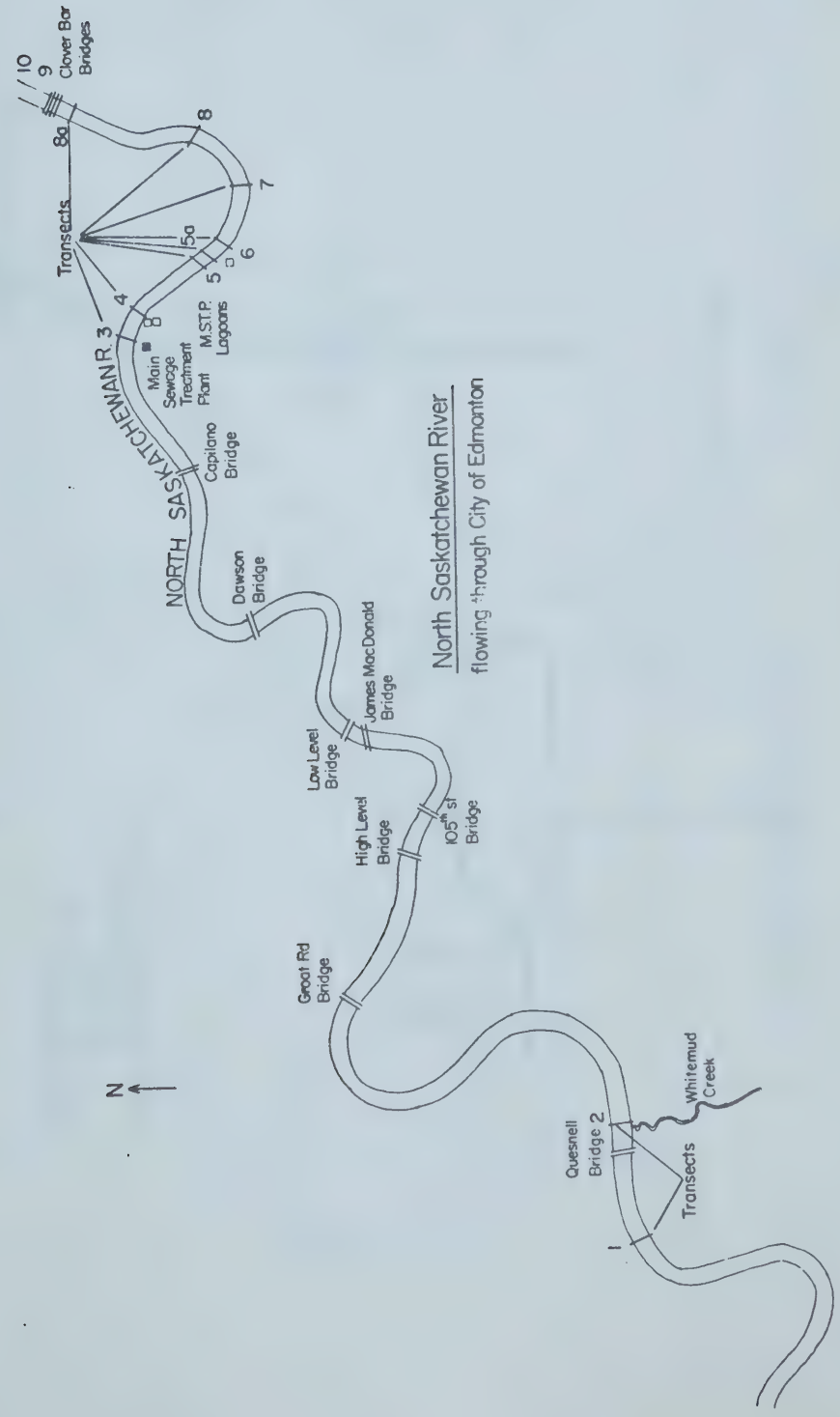

North Saskatchewan River
flowing through City of Edmonton
N
NORTH SASKATCHEWAN R.
Transects
Clover Bar Bridges
Main Sewage Treatment Plant
M.S.T.P. Lagoons
Capilano Bridge
Dawson Bridge
James MacDonald Bridge
Low Level Bridge
High Level Bridge
105th St Bridge
Groat Rd Bridge
Quesnell Bridge
Whitemud Creek
Transects

FIGURE II

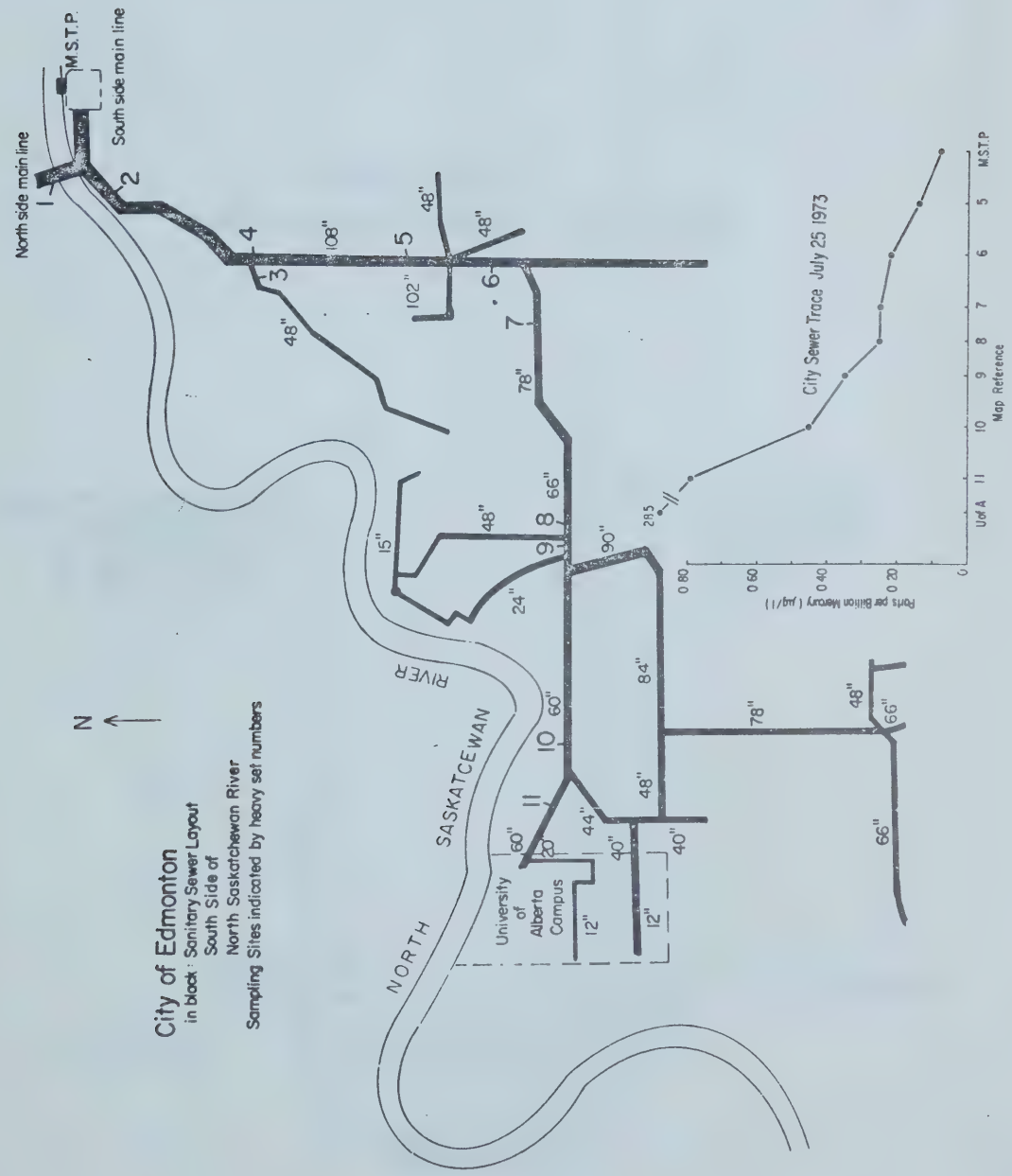

City of Edmonton
in black : Sanitary Sewer Layout
South Side of
North Saskatchewan River
Sampling Sites indicated by heavy set numbers
N
North side main line
South side main line
M.S.T.P.
NORTH SASKATCHEWAN RIVER
University of Alberta Campus
City Sewer Trace July 25 1973
Parts per Billion Mercury (µg/l)
Map Reference
U of A
M.S.T.P

FIGURE III

Sewer Manhole
Public Health Building, North Wing

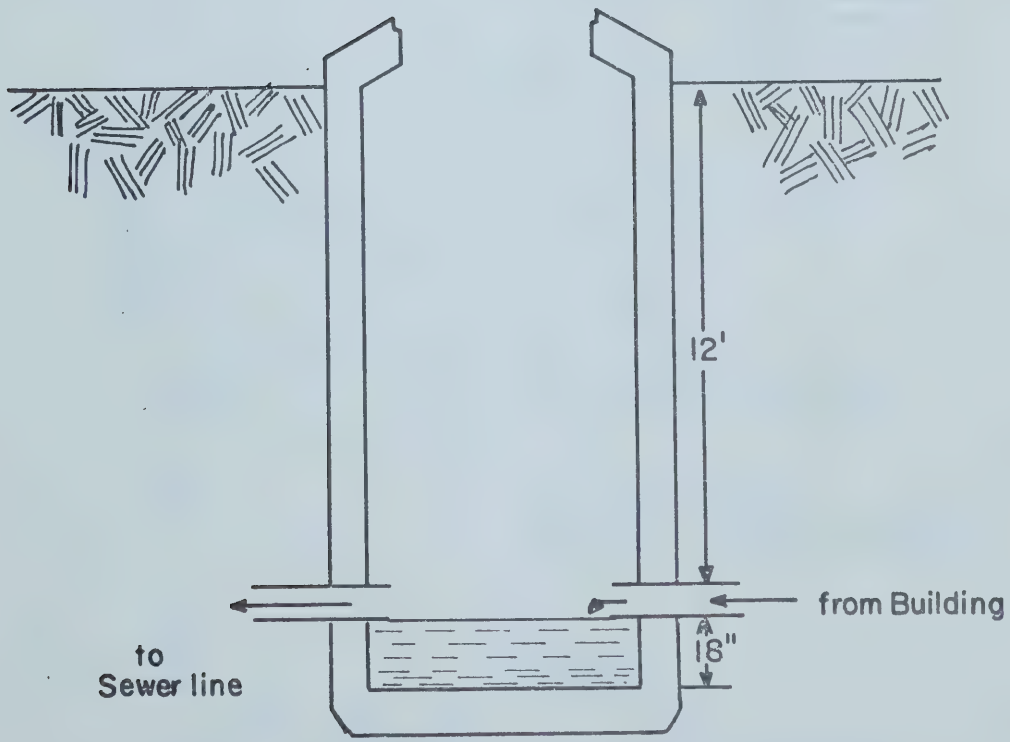
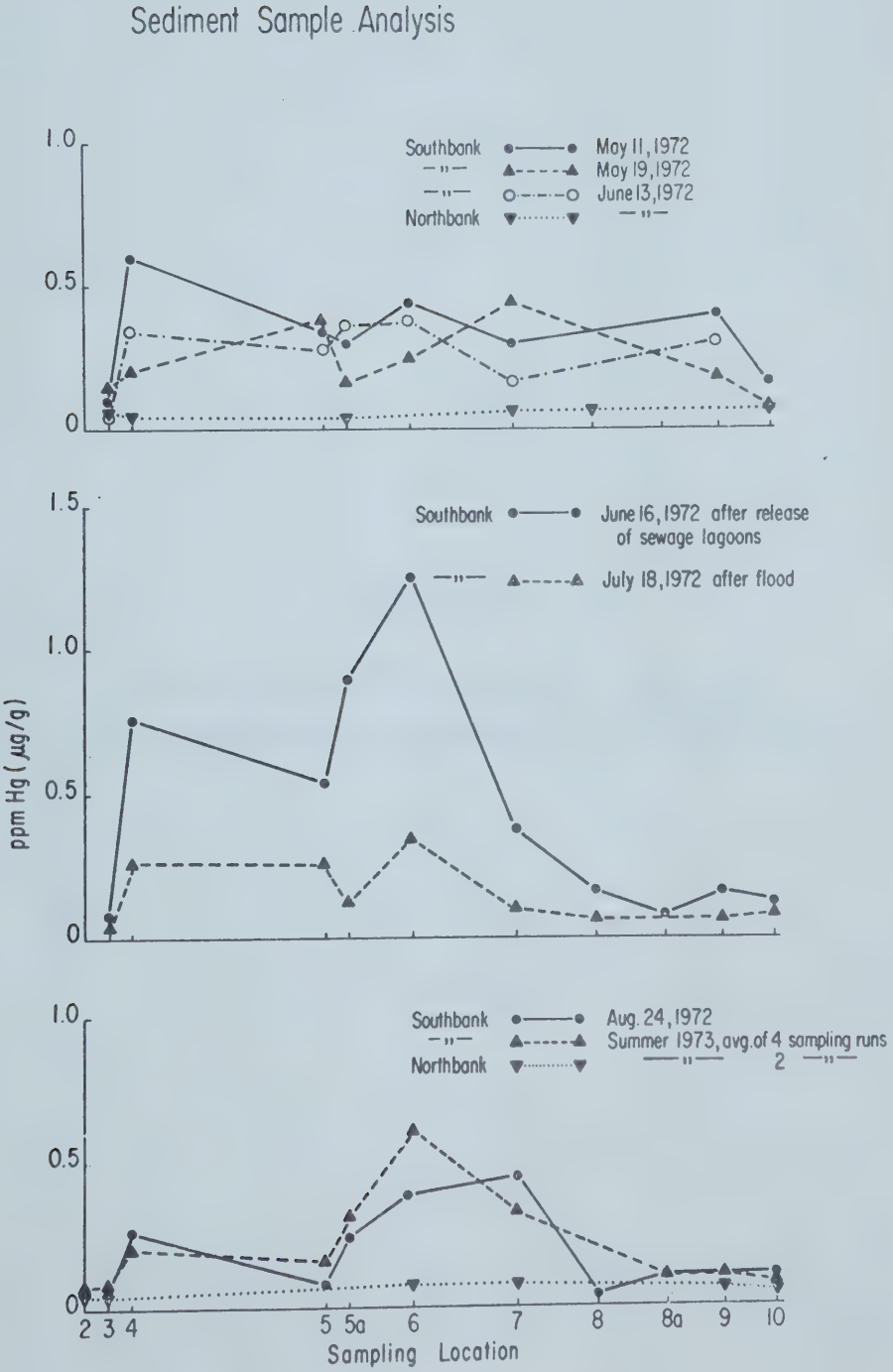


FIGURE IV


Sediment Sample Analysis
Southbank
—"—
—"—
Northbank
May 11, 1972
May 19, 1972
June 13, 1972
—"—
June 16, 1972 after release of sewage lagoons
July 18, 1972 after flood
Aug. 24, 1972
Summer 1973, avg. of 4 sampling runs
2 —"—
ppm Hg (µg/g)
1.5
1.0
0.5
0
2 3 4 5 5a 6 7 8 8a 9 10
Sampling Location

SECTION II

Mercury Levels in Sediments, Invertebrates, and Fish from the North Saskatchewan River in Alberta

INTRODUCTION

The North Saskatchewan River, with headwaters arising in the Rocky Mountains, is part of the Lake Winnipeg Drainage System. It is a large, turbid, turbulent river with a total length in Alberta of 3,500 km and a drainage of 93,700 km. The river basin is covered by glacial drift which, being easily eroded, results in steep banks on the outside of bends and gravel flood plains on the inside. Where the river flow is rapid, the substrate consists of rubble and gravel, while in slower moving portions of the river, the substrate is composed of soft mud and sand. (Paterson, et al).

Total mercury determinations were performed by the Freshwater Institute in Winnipeg for the Alberta Department of Lands and Forests, on the axial muscle of a restricted number of fish caught in the North Saskatchewan River in Alberta between 1969 - 1971. A number of fish of several different species possessed levels of mercury well in excess of the 0.5 ppm limit set by the Health Protection Branch in Canada. (Paterson, 1970).

In Alberta, the City of Edmonton, Population 400,000 is the major contributor of pollutants from industrial and sanitary sewage wastes to the North Saskatchewan River (Kupchanko, 1969 - 72). A two year study (Munson et al., 1973) completed in conjunction with this project, revealed that the City of Edmonton was contributing small amounts of mercury to the North Saskatchewan River via effluent outfalls and that this mercury was detectable in the bottom sediments. No other significant sources were detected along the river from the Brazeau Dam to the Saskatchewan Border.

The purpose of this study was to determine the levels of mercury present in the fish in the North Saskatchewan River in Alberta and, if possible, to determine the origin of the mercury in these fish. During the summer of 1973, 204 fish comprising five species, were caught at various locations along the North Saskatchewan River extending eastward from the Brazeau Dam to the Saskatchewan Border. Total mercury

analysis was performed on axial muscles and stomach contents from these fish, together with bottom sediments and aquatic invertebrates sampled from similar locations and at similar times.

MATERIALS AND METHODS

Fishing by means of gill nets of 1 1/2" - 3 1/2" mesh was carried out from June 1973 through August 1973 in the North Saskatchewan River at locations extending from the Brazeau Dam to the Alberta-Saskatchewan border (Fig. 1). After capture, the standard length of the fish was recorded. Stomach contents were examined and analyzed for total mercury content. Duplicate samples of axial muscle were removed from each side of the mid-line, anterior to the dorsal fin, for total mercury analysis. Sediment samples and invertebrate fauna were collected at each sampling location and analyzed.

Total mercury determinations were done by cold vapour atomic absorption spectroscopy, following digestion in nitric acid, sulfuric acid and potassium permanganate (Armstrong et al.), 1971.

National Bureau of Standards, Standard Reference Material, Orchard leaves, 1571, were analyzed for total mercury content and determined by our method to be an average of 0.147 ± 0.056 ppm dry weight on 8 samples, with a sample size of 0.05 gm - 0.20 gm. The reported value was 0.155 ± 0.015 on a minimum recommended sample size of 0.25 gm. A lower sample size was used because of problems in digesting the larger sized sample of plant meterial using our procedure. Recovery of mercuric chloride was 92% - 105% of methylmercuric chloride was 87% - 92 % recovery; when mercury was added to samples.

RESULTS AND DISCUSSION

The aquatic environment of the North Saskatchewan River in Alberta is not mercury free; however, there does not appear to be a mercury contamination problem. Total mercury analysis performed on bottom sediments and aquatic invertebrates taken from this river at various locations (Fig. 1) in Alberta revealed that mercury (Tables 1 & 2) was present but at levels indicative of a non-mercury polluted environment. (Hartung 1972; Konrad 1971). In a small portion of the total sampling

area, the City of Edmonton mercury levels were elevated slightly but significantly, above background levels were found in bottom sediments (Munson et al., 1973). These mercury levels, which originated from industrial wastes and sanitary sewage outfalls in the Edmonton area, were restricted to the south bank of the river. This mercury returned to background levels within short distances downstream of the source.

Throughout the summer of 1973, fishing by means of gill nets at the locations indicated on Fig. 1, yielded 204 fish comprising five (5) species. Table 3 lists the values for the total mercury analysis performed on the axial muscle of these fish.

Four (4) species of these fish (three species of sucker, Catostomus commersoni, Catostomus catostomus and Moxostoma macrolepidotum, occupying the lower levels of the fish food chain and the single species of pike, Esox lucius, which occupies an upper level of the food chain), contained mercury levels below the 0.5 ppm limit set by the Health Protection Branch on consumable fish and meat. All four species of these fish possessed mercury levels indicative of the non-mercury polluted environment from which they were taken.

One species of fish, goldeye, Hiodon alosoides, which is the most abundant fish in the North Saskatchewan River (Paterson 1966 & 1974) comprised 70 per cent of our sample population and possessed mercury levels averaging in excess of 1.0 ppm. The levels of mercury found in the goldeye are not indicative of the background levels found in most of their environment. Goldeye, occupying a midpoint in the fish food chain, might have been expected to possess levels of mercury higher than that found in suckers (given similar exposure), owing to trophic level magnification. This was observed; however, pike, near the top of the food chain, had mercury levels similar to those in suckers and less than those in goldeye. In addition, Fig. 2 illustrates the lack of any correlation between body size and mercury content in goldeye.

The City of Edmonton is the major contributor of pollutants, including mercury, to the North Saskatchewan River in Alberta. Therefore our samples were separated into populations caught upstream and downstream of the probable pollution sources. The division point was

50th Street in the City of Edmonton, as pollutants entering the river from the Edmonton area do so downstream of this point. Table 4 illustrates the upstream-downstream split for each species caught. The three species of sucker and single species of pike showed virtually no difference in mercury levels when each was separated into upstream and downstream populations. The division of goldeye into upstream and downstream populations produced unusual results in that the upstream population was significantly higher than the downstream. There was no corresponding increase in the mercury levels in the upstream environment as indicated by sediment and invertebrate analysis. ($T = 3.482$; $P < 0.05$ by unpaired two-tailed t-test).

These results suggested the following questions;

(1) Where and how did Goldeye accumulate such high mercury levels in a relatively mercury-free environment?

(2) What the reason was for the upstream-downstream distribution of the mercury levels in Goldeye?

The Goldeye is a freshwater fish of the mooneye family, Hiodontidae, of which representatives are found only in North America. In Western Canada, Goldeye are found in the Saskatchewan River system, Churchill River, Athabasca River, Peace River, Slave River, MacKenzie River, Red Deer River, plus several others. They are the most abundant fish in the North Saskatchewan River and they are reported to prefer muddy, silty, deeper waters. According to various studies, they migrate in the spring, at ice breakup, to spawn and then return to deeper waters in late autumn to overwinter. The combination of water temperature and water level were suggested to be the keys to the timing of migrations. (Kennedy, 1967). There is considerable speculation as to the distances which these fish will migrate (Kennedy 1967; Kooyman 1972). Goldeye, occupying a midpoint in the fish food chain, possess a wide food preference or unstructured food web. They are opportunity feeders, i.e., they will consume that portion of their food web which happens to be in the most abundance. Knowledge of Goldeye physiology and pharmacology is non-existant and the effects of mercury on this species is unknown. Basic knowledge such as the rate of uptake of mercury, its mode of uptake, i.e., via the gut or gills, its retention and elimin-

ation rate, as well as the distribution of mercury in the body of these fish is, at present, unreported. We particularly lack knowledge of the effects of chronic low level exposure to mercury by Goldeye.

In light of this information gap, several hypotheses as to the origin and distribution of mercury found in Goldeye from the North Saskatchewan River in Alberta can be considered.

First, Goldeye may accumulate their mercury in Alberta through chronic low level exposure. This implies that a physiological characteristic unique to the Goldeye exists such that their exposure, either while migrating through the slightly polluted Edmonton area, or while exposed to the low levels of mercury that exist in the remaining part of Alberta, caused the higher mercury accumulation than that found in other fish species. However, it is difficult to explain why Goldeye in Saskatchewan, in a mercury contaminated environment, do not exhibit a comparatively higher mercury content when compared to the same fish species studied here (Summer 1970; Wobeser, 1970).

A second hypotheses is related to mercury persistence in fish. The half life of mercury in fish is reported to be in excess of 400 days (Lockhart 1972; Jarvenpaa 1973). The North Saskatchewan River environment in Alberta appears relatively free of mercury. Assuming Goldeye can migrate considerable distances, then, because of the extended half life of mercury in fish, fish caught in Alberta may contain residue mercury acquired elsewhere. The Goldeye may be exposed to high levels of mercury in a wintering area, and in the spring migrate into Alberta with their winter's accumulation of mercury.

This hypotheses requires the existance of a relatively deep overwintering area with a history of mercury pollution that is within the range of migration from our sampling sites in Alberta. Fig. 3 illustrates one possible area, Tobin Lake in Saskatchewan, a reservoir created by the Squaw Rapids Dam on the Saskatchewan River. This reservoir or lake is located downstream of the chlor-alkali plant in Saskatoon, which has a history of serious mercury contamination of the river environment (Bligh 1970; Sumner 1970; Wobeser 1970).

We do not know the extent of any mercury problem in Tobin Lake and we do not know if Goldeye from Tobin Lake can and/or will migrate the considerable distances necessary (200 - 400 miles) to bring them to our sampling areas in Alberta. To test this hypothesis, more data is required on the mercury contamination of Tobin Lake and on the mercury levels of fish in and migration from Tobin Lake.

The observed differences in the mercury levels of Goldeye sampled upstream and downstream of Edmonton must also be explained and several hypotheses will be examined.

First, what we may be observing is simply a matter of biological variation created by sampling error. However, with 67 fish caught downstream and 74 caught upstream, both over a three month period, this would seem unlikely.

Second, a migrating population of Goldeye entering Alberta with relatively high mercury levels accumulated over the winter from a mercury contaminated environment, may, on entering the relatively mercury free environment present in Alberta, gradually eliminate some of their mercury burden. This would lead to the prediction of lower mercury levels upstream, which of course, was not observed. However, as these fish pass through the Edmonton area on their way upstream, they may be exposed to the small amounts of mercury present in this area, which may cause a further accumulation of mercury to occur, thus accounting for the observed higher levels of mercury in the upstream population. Neither the residence time of Goldeye in the Edmonton area nor the dynamics of mercury accumulation, as previously noted, are presently known.

The mercury in the Edmonton area is mainly restricted to the south bank of the river, as are a multitude of other adverse pollutants associated with effluent outfalls which would severely limit the availability of food on this bank (Paterson 1966 & 1969). If the presence of an adverse environment, coupled with a scarcity of food on the south bank of the river in the Edmonton area caused the fish to avoid this area and pass through the Edmonton area on the north bank, which possesses only background mercury levels, then

the above hypotheses would be untenable.

A third hypothesis couples the migrating population theory with the probability that there may be a resident population of Goldeye which are exposed to low levels of mercury present in the North Saskatchewan River in Alberta and a migrating population exposed to different levels "elsewhere".

When the Goldeye data is analysed on a monthly basis there appears to be a decrease with time in the mercury levels in both the upstream and downstream populations of Goldeye, especially the downstream population. In June the Goldeye population downstream may have consisted of a small resident population, containing low mercury levels and a large migrating population, with high mercury levels, that was moving through the area. As the summer progressed, the absolute numbers of individuals comprising this migrating population decreased as it had moved through the downstream sampling areas, leaving the small resident population to comprise a greater percentage of fish caught per set, i.e., five per cent of the fish caught in June would be resident while 78 per cent of those caught in August would be resident (Fig. 4). If this theory is correct then the upstream sample of Goldeye would indeed show higher levels of mercury especially as the summer progressed. The observed slight decrease in the percentage of the population containing greater than 0.5 ppm mercury in the upstream sample as the summer progressed is indicative of natural elimination by members of the population in a mercury free environment.

CONCLUSION:

The North Saskatchewan River in Alberta does not have a major mercury source, nor does it have a major mercury contamination problem. Four species of fish taken from this environment, three species from the low end of the fish food chain and one from the upper end of the food chain, possess mercury levels below the 0.5 ppm standard and these levels of mercury are indicative of the non-mercury contaminated environment from which they are taken. The mercury levels in Goldeye which constitute the most frequent component of the fish population in the North Saskatchewan River, exceeded the 0.5 ppm

standard by a significant amount and these levels are indicative of exposure to mercury pollution.

Either these fish accumulate these high levels of mercury elsewhere during the winter and then migrate into Alberta in the early spring to spawn, or through some physiological abnormality they accumulate the mercury in Alberta from the very low levels of contamination present here.

Several hypothesis are presented as to the possible explanation for the observed higher concentration of mercury in the upstream population of Goldeye when compared to the downstream population. At present we lack information on the migratory habits of Goldeye in the North Saskatchewan River and we require a much greater insight into the physiological reaction of Goldeye, both to acute and chronic exposure to mercury contamination. Both of these areas are the subject of a further study which is presently in progress.

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TABLES & FIGURES

FIGURE I - Map of the North Saskatchewan River - showing various locations where bottom sediments and aquatic invertebrates were taken from in this river.

FIGURE II - Mercury content of individual Goldeye, according to length, in the North Saskatchewan River.

FIGURE III - Map of the Saskatchewan River System in Saskatchewan - shows Tobin Lake which has a history of serious mercury contamination of the river environment.

FIGURE IV - The percentage of the population of Goldeye containing greater than 0.5 ppm of mercury in the upstream and downstream sample in the summer of]973.

TABLE I - Sediment Mercury Analysis in the North Saskatchewan River in 1973

TABLE 2 - Aquatic Invertebrate Mercury Analysis at different sites in 1973.

TABLE 3 - The mean amount of mercury for each species of fish caught in the North Saskatchewan River in Alberta during the summer of 1973.

TABLE 4 - Illustration of the upstream-downstream split for each species of fish caught in the Edmonton region.

TABLE I

Sediment Mercury Analysis - North Saskatchewan River 1973

Site	Hg ppm
Upstream of Edmonton*	
2 - Brazeau Dam	0.14
1 - Brazeau Reservoir	0.14
4 - Genesee Ferry	0.10
5 - Genesee Bridge	0.07
6 - Devon	0.05
7 - Big Island	0.05
8 - Whitemud Creek	0.06
Downstream of Edmonton*	
9 - Edmonton Power Plant	0.12
- Fort Saskatchewan	0.07
10 - Sherritt Gordon Pumphouse	0.07
11 - Mouth of Sturgeon River	0.10
12 - Upstream of Redwater River	0.06
13 - Redwater River-mouth	0.09
14 - Weskatenau Bridge	0.06
15 - Duvernay Bridge	0.10
16 - Lloydminister Ferry	0.09

*Upstream-downstream division made at 50th Street - City of Edmonton

TABLE 2

Aquatic Invertebrate Analysis - N.S.R. - 1973

Site	Species	Hg - ppm
2 - Brazeau Dam -	Gammarus	0.07
3 - Drayton Valley -	Ephemeroptera Ephemerella	0.03
	Plecoptera Aconeuria	0.02
4 - Genesee -	Ephemerella Heptagena	0.07
	Plecoptera Isogenus	0.02
7 - Big Island	Ephemeroptera Rithrogenia Ephemerella Heptagenia	0.04
9 - Edmonton Power	Ephemeroptera	0.11
	Plecoptera	0.21
	Gammarus	0.03
11 - Sturgeon River	Ephemeroptera	0.09
	Plecoptera	0.09
14 - Waskatenau Bridge	Heptagenia	0.10
	Ephemerella	0.10
	Plecoptera	0.02

TABLE 3

Mean ppm Hg for each species of fish caught in the North Saskatchewan River in Alberta - June 1973 - August 1973

Species	Aug. ppm	Number
Goldeye *Hiodon alosoides*	1.02	141
White Sucker *Catostomus commersoni*	0.23	25
Longnose Sucker *Catostomus catostomus*	0.39	23
Redhorse Sucker *Moxostoma macrolepidotum*	0.47	6
Northern Pike *Esox lucius*	0.31	10

TABLE 4

Upstream-Downstream Split for each Species

Species	Upstream Hg ppm/No.	Downstream Hg ppm/No.
Goldeye	1.22/74	0.82/67
White Sucker	0.22/13	0/23/12
Longnose Sucker	0.38/15	0..39/12
Redhorse Sucker	0.48/3	0.46/3
Northern Pike	0.29/8	0.33/2

FIGURE I

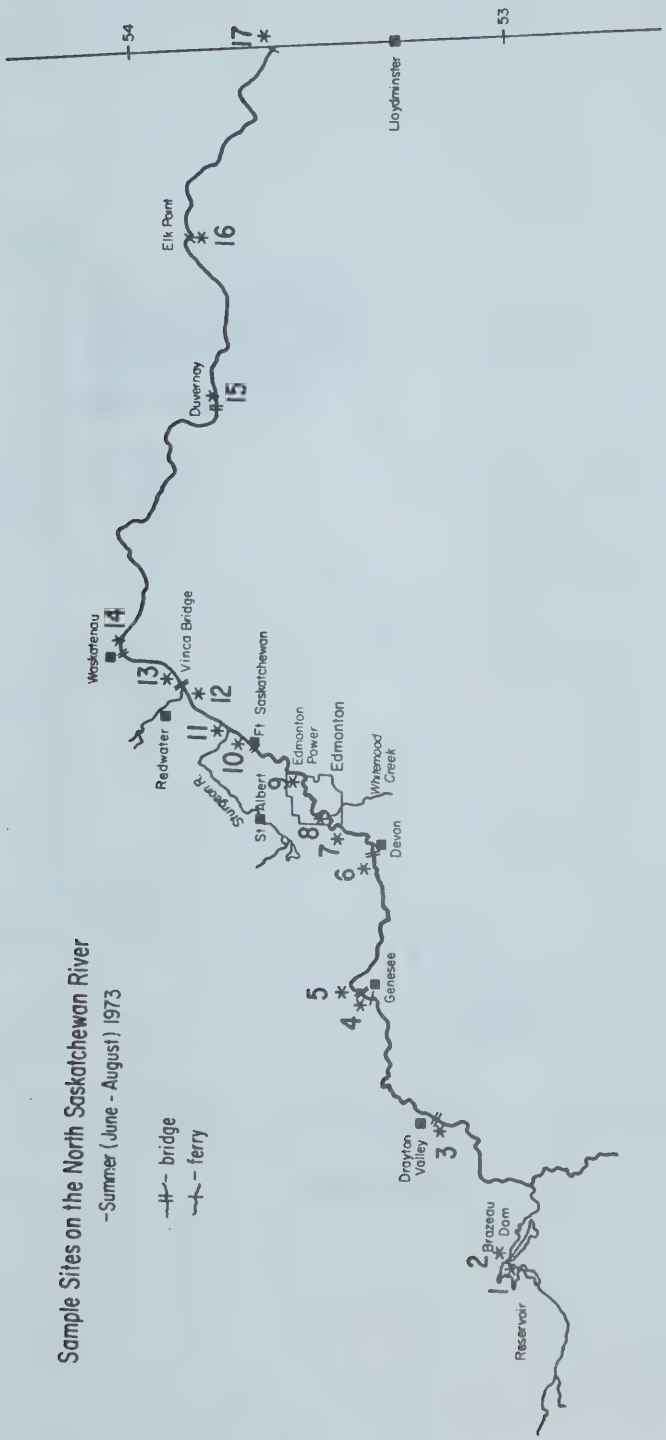

Sample Sites on the North Saskatchewan River
-Summer (June - August) 1973
bridge
ferry
54
53
17
Lloydminster
Elk Point
16
Duvernay
15
Waskatenau
14
Vinca Bridge
13
12
Redwater
11
Ft Saskatchewan
10
Sturgeon R.
St Albert
9
Edmonton Power
Edmonton
Whitemud Creek
8
7
6
Devon
5
4
Genesee
Drayton Valley
3
2
Brazeau Dam
1
Reservoir

FIGURE II

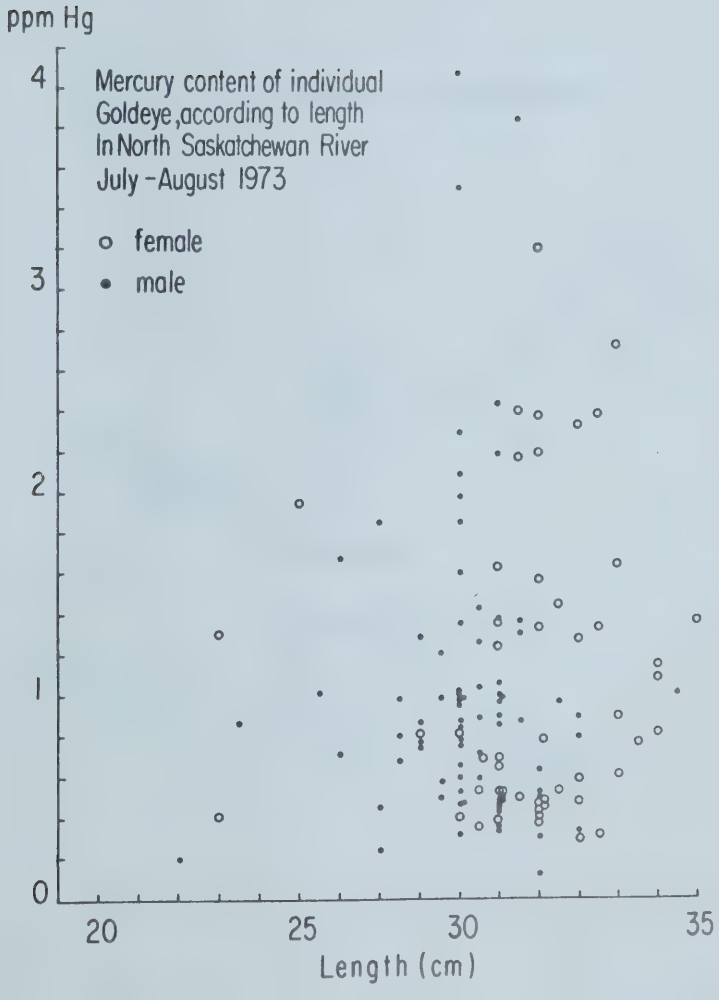
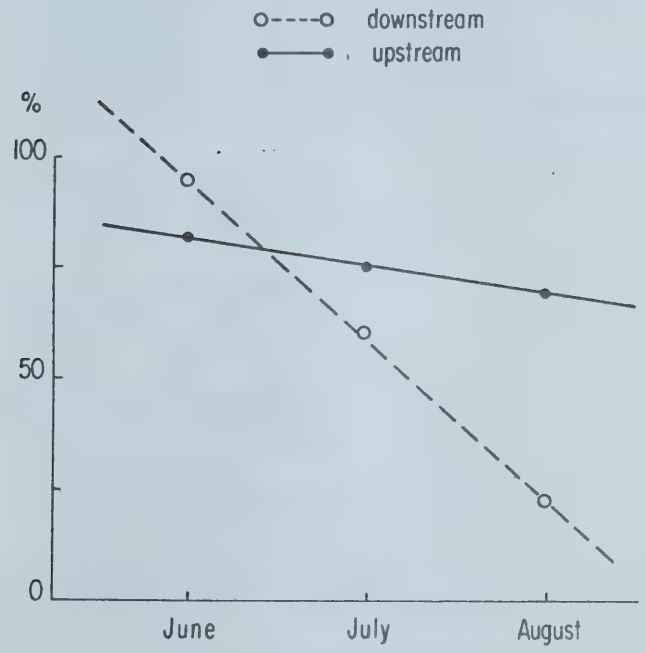

ppm Hg
Mercury content of individual
Goldeye, according to length
In North Saskatchewan River
July - August 1973
o female
• male
4
3
2
1
0
20
25
30
35
Length (cm)

FIGURE III

Saskatchewan River System in Saskatchewan

FIGURE IV

Goldeye containing >0.5 ppm Hg, sampled June, July, August 1973



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Atlas Construction Ltd.
Chrysler Outboard Motor Ltd.

Mr. B. Diefenbach
Great West Steel Ltd.
Mr. M. Russnak
W.W. Arcade
Madison Marine Ltd.
Canada Safeway Ltd.
Todd Cleaners
Prodor Construction Co. Ltd.
Jasper Printing Ltd.
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Master Motors Ltd.
Excel Auto Service Ltd.
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